GREENLAND SEA CURRENTS

TECHNICAL REPORT

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Technical Report Summary

Introduction

The Greenland Sea holds a position of unique importance and interest among all the Arctic seas. There are two essentially different reasons for this.

One, the northern portion constitutes the major connection of the Arctic Basin with the rest of the world ocean, both in terms of depth and cross-sectional area, and in terms of the actual flow of water (cf. Coachman and Aagaard, in press). No satisfactory heat and mass budgets for the Arctic can be constructed without a considerable improvement in our knowledge of the heat and mass transports through the Greenland Sea. There is evidence that the present budgets may have underestimated the actual transports through the Greenland-Spitsbergen passage by one-half order of magnitude, and that the internal transports in the Greenland Sea have been underestimated by a full order (Aagaard and Coachman, 1968a). It is certainly clear that the dominant barotropicity of the area makes it impossible to substitute dynamic calculations based on temperature and salinity measurements for direct current observations (Aagaard and Coachman, 1968b).

Two, the Greenland Sea (and the Norwegian Sea, together with which it forms an intricately combined system) is a large, deep, partially ice-covered sea; it is one of the northern hemisphere's primary heat exchangers (cf, e.g., Fletcher, 1965), and as such of vital importance in the total global energy budget; it routinely permits navigation farther north than anywhere else in the world; it is the principal northern source of deep water for the world ocean; it exhibits a circulation of the same order of magnitude as the Gulf Stream system. In all these ways it is an area of great importance and interest in its own right.

The present problem

The single most important line of investigation to further our environmental understanding of the area must be direct current measurements. It seems clear that the logical first area of concentration should be the Greenland-Spitsbergen passage, through which the exchange with the Arctic Ocean occurs. Eventually the current measurements must extend throughout the year, for both our flow observations in the East Greenland Current (Aagaard, 1968) and our wind stress calculations (Aagaard, 1970) imply substantial seasonal differences in the circulation. However, the practical obstacles are formidable, for during winter (1) the area is largely ice-covered; (2) there is total darkness for about four months; (3) bad weather and severe icing conditions are common. Furthermore, logistics and navigation are always problematic in this part of the world.

Methods

In view of the above it was decided to deploy moored current meters, anchored for one year beneath the reach of the drifting ice. The successful deployment and retrieval of such instruments would not only avoid the problems of winter field operations, but would also represent a quantum jump advance both scientifically and technologically. That is, it would provide the urgently needed oceanographic data, and it would also be the first successful year-long current meter deployment anywhere in the world.

A total of six current meters were moored in the Greenland-Spitsbergen passage in September 1971. The mooring positions are shown in Fig. 1; a chronological exposition of the project is given in Appendix A. The meters record the current speed and direction on magnetic tape. They are designed to be recovered by acoustic activation of the explosive release mechanism which frees the mooring from its anchor. The subsurface float then rises to the surface, and the equipment is taken aboard the recovery vessel. The details of the moorings are shown schematically in Fig. 2, and described in Appendix B.

In addition a total of 27 hydrographic and chemistry stations were taken to elucidate the circulation and its relation to the internal oceanographic pressure field. Station locations are shown in Fig. 1.

Technical Results

We feel the problems of mooring design and assembly to have been solved satisfactorily, and that the deployed systems represent good and practical Arctic deep-sea current meter arrays. The actual handling of the equipment at sea and its successful deployment is to large degree a matter of good seamanship; the latter is a prime requirement in Arctic operations of this sort.

Two essential technical requirements stand out. One is the need for very accurate navigation in order to position the buoys during deployment; in the Greenland Sea this will in practice mean satellite navigation. The other requirement is high-quality directional sonar to precisely locate the buoys during recovery.

Department of Defense implications

Recovery of the current meters with their data would permit a substantial increase in our environmental understanding of the strategically and tactically important Greenland Sea. Such understanding would seem particularly essential to problems of submarine operations.

There is in addition a host of Department of Defense sponsored research in the Arctic with climatological aspects. An improved knowledge of the heat and mass exchange through the Greenland-Spitsbergen passage bears directly on these aspects.

Finally, we believe that a modest addition has been made to the fund of Arctic buoy technology and operational experience.

Implications for further research

Clearly, our first order of business must be to ensure recovery of the six current meters already deployed. To this end we have requested from the Marine Research Institute in Reykjavik, Iceland time aboard the *Bjarni Saemundsson*. This is the largest and newest of the Icelandic research vessels, a stern trawler designed for oceanographic and fisheries research and equipped with a large array of sophisticated sonar. We have now had a very favorable reply to our request, to the effect that the ship will be available in the Greenland Sea for joint Icelandic-U.S. investigations during five weeks in August-September 1972. We should note that this arrangement is extraordinary, both in the unprecedented length of time available to physical oceanography, and in permitting the vessel to operate far northward of any area thus far considered within the scope of Icelandic investigations. It is essential that we take advantage of this opportunity, both to recover the current meters deployed last year, and to fully utilize this exceptional ship in furthering our investigations in the Greenland Sea.

The primary objective of our program must continue to be direct current measurements. We therefore propose to carry out this coming summer extensive measurements using drogues. There are three reasons for this decision. One, before committing funds to further moored arrays of current meters in the Greenland Sea it behoves us to evaluate our first mooring attempts; this, of course, cannot be done until after next summer. Two, the use of drogues is a highly reliable form of current measurement, so that our results are in a sense guaranteed. Three, we have had three years of experience in the deep western Bering Sea developing the techniques involved, and we feel that we have achieved a fairly high degree of competency.

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Appendix A

A Chronological Exposition of the Project

On 16 June we were informed by the U.S. Coast Guard that they could not accomodate our personnel and equipment on board the *Westwind*, as had been planned. A subsequent exhaustive search indicated that no ship of opportunity was available, neither in Europe nor the United States. The most favorable charter arrangement available proved to be the Icelandic Coast Guard vessel *Arvakur*, a lighthouse tender of 550 gross registered tons. The charter was for a minimum period of one month at $20,000. An acceleration to the contract of $11,000 was approved by the Office of Naval Research, and all financial and logistic arrangments were completed prior to the charter commencement date of 29 August.

The design, purchase, construction, and assembly of all instruments and moorings had been completed by early July. The moorings were assembled at the Woods Hole Oceanographic Institution, for reasons of time and convenience. The equipment was then shipped to Reykjavik, Iceland and installed on board the *Arvakur*.

The ship left Reykjavik the morning of 30 August and proceeded to the mooring deployment area in the Greenland-Spitsbergen passage. We should note that the first week in August a serious complication had arisen: the *Arvakur* proved to have no echo sounder usable in deep water, whereas a precise knowledge of the water depth is required for mooring deployment. A lease was then arranged for a precision depth recorder from Ocean Sonics in California and the equipment air freighted to Iceland. The instrument proved to be faulty, and a total of six days ship time was lost effecting repairs at sea under primitive conditions. The kind services of the station leader at Isfjord Radio, Spitsbergen proved indispensable. The three moorings were finally deployed on 8 and 10 September, the echo sounder difficulties having forced relocation of one of the moorings from 2000m to 1000m depth. Each mooring carried two current meters, and their deployment was as follows: mooring #1, at 78°33'N, 2°21'E, in 2465m depth, with current meters at 121m and 1365m; mooring #2, at 78°55'N, 8°6'E, in 992m depth, with current meters at 146m and 942m; mooring #3, at 78°37'N, 8°14'E, in 982m depth, with current meters at 132m and 582m. The deployment was successful in every respect, and the acoustic release near the bottom of each mooring replied upon command after emplacement, indicating they were upright and functioning.

The ship then proceeded northeast, into light winter ice, and at 81°N, 16°E began a series of eight detailed chemistry stations north of Spitsbergen, in depths up to 2000m. These stations were designed to elucidate the entry and mixing in the Polar Basin of water from the West Spitsbergen Current. Next, eight hydrographic stations were taken

around the moored buoys, for the purpose of determining the internal mass field and its relation to the measured currents. Finally, a series of 11 hydrographic stations along the Greenwich meridian from 79° to 72°N, and between Jan Mayen and Iceland were occupied. The ship arrived back in Reykjavik during the afternoon of 27 September, and all equipment was offloaded and trucked to Keflavik the same day for shipment to the United States.

Among the difficulties occurring during the cruise were poor navigation conditions (much of the time we had only one Loran line and a taff rail log) and primitive hydrographic equipment. No problems proved beyond solution.

Reduction of the hydrographic data is proceeding apace and should be completed in early 1972.

Appendix B

Description of Moorings

A typical mooring, as depicted schematically in Fig. 2, is made up as follows. At top, submerged some 70-90m below the surface, is a steel float, 4 ft. in diameter, and with a net buoyancy of about 1500 lb. It was supplied by O&M of Falmouth, Massachusetts. On special order it was provided with a Dimetcote finish for corrosion resistance purposes.

Using 3/4" galvanized safety anchor shackles with stainless steel pins, a second float is connected immediately below the first.

Shackles of the same type connect the second float to the top of the mooring line, which has been eye spliced and fitted with a galvanized thimble. The mooring line is 9/16" plaited Dacron of 8000 lb. nominal rated breaking strength. It was supplied by Columbia Rope Co. of Auburn, New York. Samples of the production order were tested by us on a tensile strength machine, so that we might accurately predict the stretching under load and thus place the floats at a predicted depth.

The first mooring line terminates in a 316 stainless steel thimble fitted in an eye splice. Unfortunately, the rope supplied by the manufacturer was oversize, and since the thimbles had already been purchased and time did not permit reordering, a short piece of 9/16"plaited Dacron fitted with the thimble, had to be short spliced to the main mooring line. Considerable care was taken in all splicing.

Fitted into the thimble is a 316 stainless steel double-eyed plate specially machined to connect the current meter to the mooring rope. The current meter itself senses speed with a rotor magnetically coupled through the pressure case to the gear train. Direction is sensed by magnetic orientation of the meter, which is equipped with a large vane and is free to swivel. The meter also carries a temperature sensor. All data are logged in binary form on magnetic tape. The meter is supplied by Ivan Aanderaa in Bergen, Norway. We had changed the clock cams and gear trains on four of the meters to set the sampling rate at once per hour, thus enabling us to measure for an entire year. On two of the six meters, however, we used a sampling rate of once per ten minutes. This should enable us to better estimate the effects of sparse finite sampling in what is no doubt a flow regime with fairly high accelerations.

The current meter is battery-powered, as is the acoustic release, and we took considerable care to minimize the possibility of battery failure. The battery purchase was made from fresh stock just before departing for Iceland, and the batteries were all refrigerated and hand carried. Before deployment they were tested under load.

The bottom of the current meter is joined to the next piece of mooring line exactly as is done on the top, and the second current meter is similarly fitted into the mooring. At the bottom of the third mooring line, below the second current meter, the acoustic release is connected by 9/16" stainless steel safety shackle and pin to the stainless steel thimble-fitted eye splice in the mooring line. The acoustic release is designed to reply upon command from the ship, for locating purposes. A second command permits firing of the squib-activated release mechanism; after release, the instrument emits acoustic signals continuously to aid in recovery. It is also equipped with a tilt-sensing device and acoustic relay to determine its vertical orientation *in situ*. The commands utilize a five-level coding system to prevent actuation by ambient noise, and each release employs different frequencies. The instrument is manufactured by AMF in Alexandria, Virginia.

The release mechanism is connected to the anchor rope through a 316 stainless steel ring fitted through a stainless steel thimble in the eye-spliced anchor rope. The latter is a 20m length of 7/8" braided nylon with a nominal rated breaking strength close to 20,000 lbs. The lower end of the anchor rope is again eye spliced, fitted with a galvanized thimble, and connected to the anchor bridle with a 3/4" galvanized safety anchor shackle (stainless steel pin).

The anchor is of the Stimson type and cast in two pieces, totaling 5000 lbs. The pieces are joined by heavy welded straps, with chain shackled on for extra safety. The anchor bridle is of 5/8" galvanized proof coil chain, and 3/4" galvanized safety anchor shackles with stainless steel pins are used throughout. The anchors were cast at Waterbury Foundry, Waterbury, Connecticut.

The moorings were deployed from the open fantail. The floats were launched first, while the ship maintained steerage way. This both enabled the ship to steer along a depth contour to maintain the predetermined launching depth, and it also kept the mooring line taught as it was being paid out. This is absolutely essential. The moorings had been assembled beforehand, with all splices done, thimbles fitted, etc.; the completed mooring line had then been wound on large gillnet reels fitted on a frame equipped with dual hydraulically controlled trailer disc brakes. The frame was welded to the ship's deck, and we thus had very positive control of the mooring line as it was paid out behind the ship. When the appropriate amount of line had been paid out, the line was stopped off by a device designed to hold the thimble-fitted eye splice without damage to the rope. The current meter was joined to the mooring line, and the mooring line paid out again. This procedure was repeated until the entire mooring line with instruments was laid out abaft the ship. The anchor was then pushed over the side and the whole array allowed to free-fall. A constant check was made on depth and position during the deployment. After the mooring was in position it was acoustically interrogated.

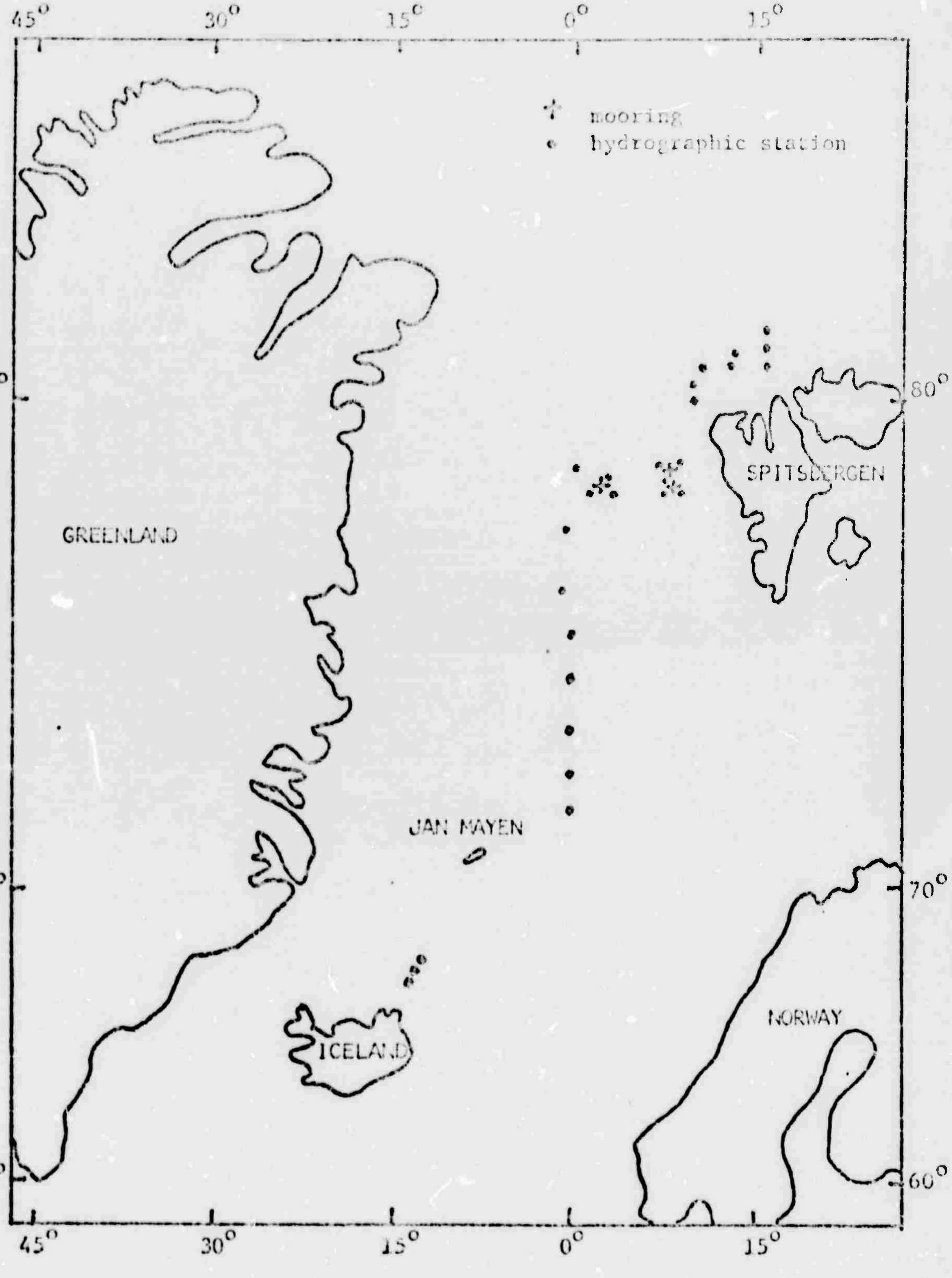

FIGURE 1. MOORING AND HYDROGRAPHIC STATION LOCATIONS

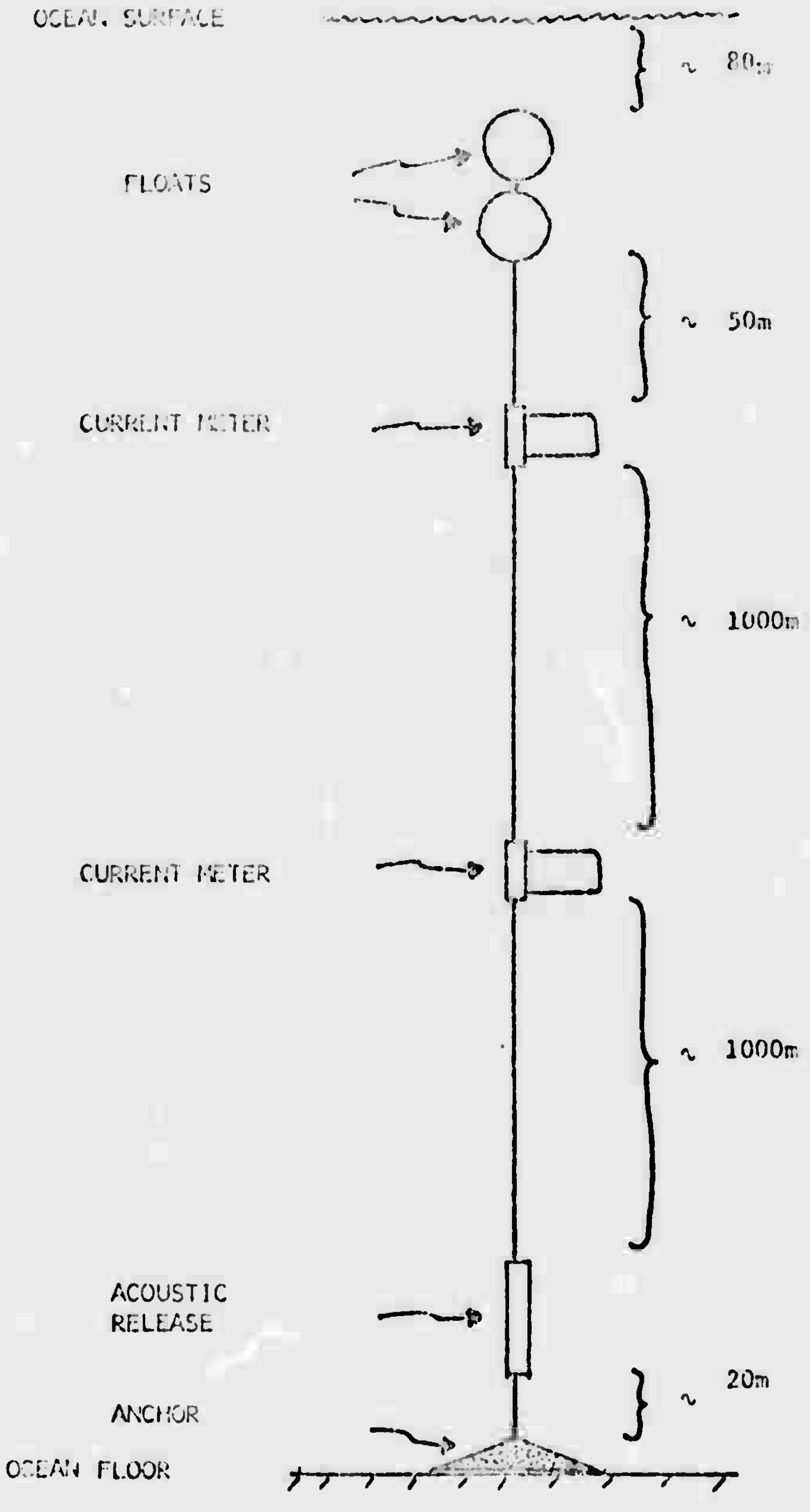

FIGURE 2. SCHEMATIC PICTURE OF A TYPICAL MOORING